Detector development for very long baseline neutrino experiment

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Ldrd #06-004

Midyear review 8/16/2007

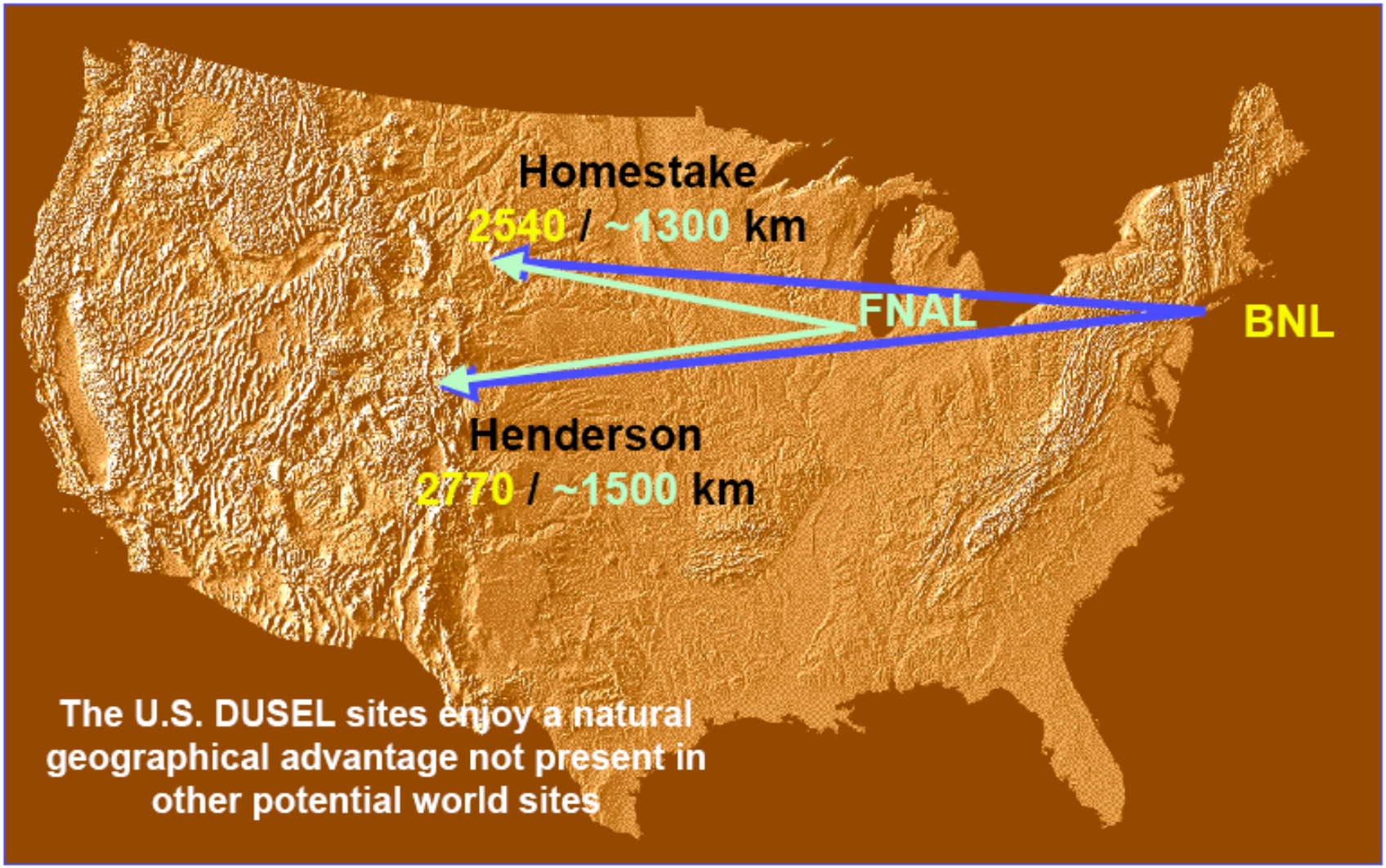
List

- Basic idea of sending a high intensity wide band beam to a very large underground detector over >1000 km remains solid.
- Participation in DUSEL process. Completed with Homestake chosen by an NSF panel.
- Examination of FNAL based beam and simulations. Completed with the FNAL-BNL report.
- Preliminary examination and proposal for a 300 kT detector in Homestake completed. Document part of FNAL-BNL study.

DUSEL Process

- S1 (Science case) process complete with a report. M.D. was one of the group leaders.
- S2 process complete with Homestake and Henderson sites chosen. M.D. is on the executive committee of Homestake and one of the Senior Personnel.
- Homestake CDR completed. MD is one of the authors.
- Homestake-DUSEL is led by LBL. MD is one of senior personnel.
- Site Decision on DUSEL on July 10, 2007. Homestake chosen as the site. Our participation and work on the large detector was certainly an important factor.
- http://www.nsf.gov/news/news_summ.jsp?cntn_id=109694&org=NSF&from=news

Super Neutrino Beam to DUSEL Candidate Sites



The US long baseline neutrino experiment study

http://nwg.phy.bnl.gov/fnal-bnl

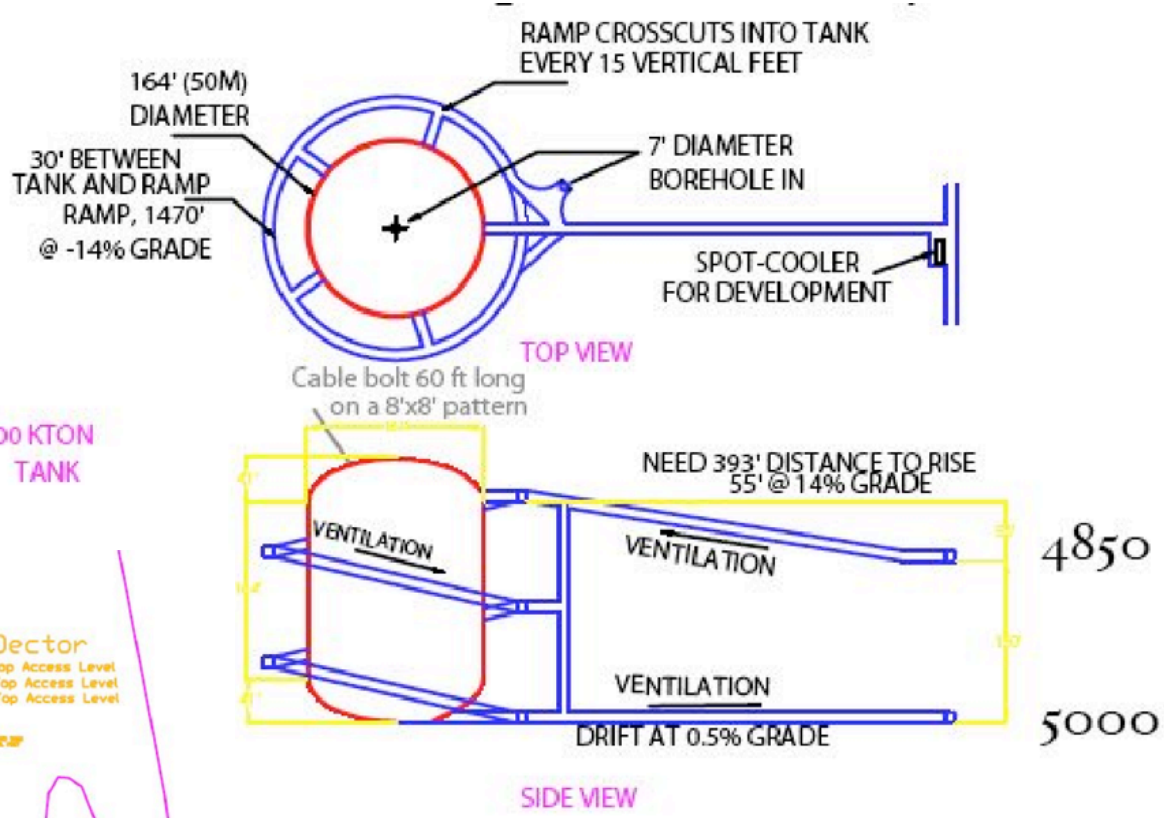
The US long baseline neutrino study

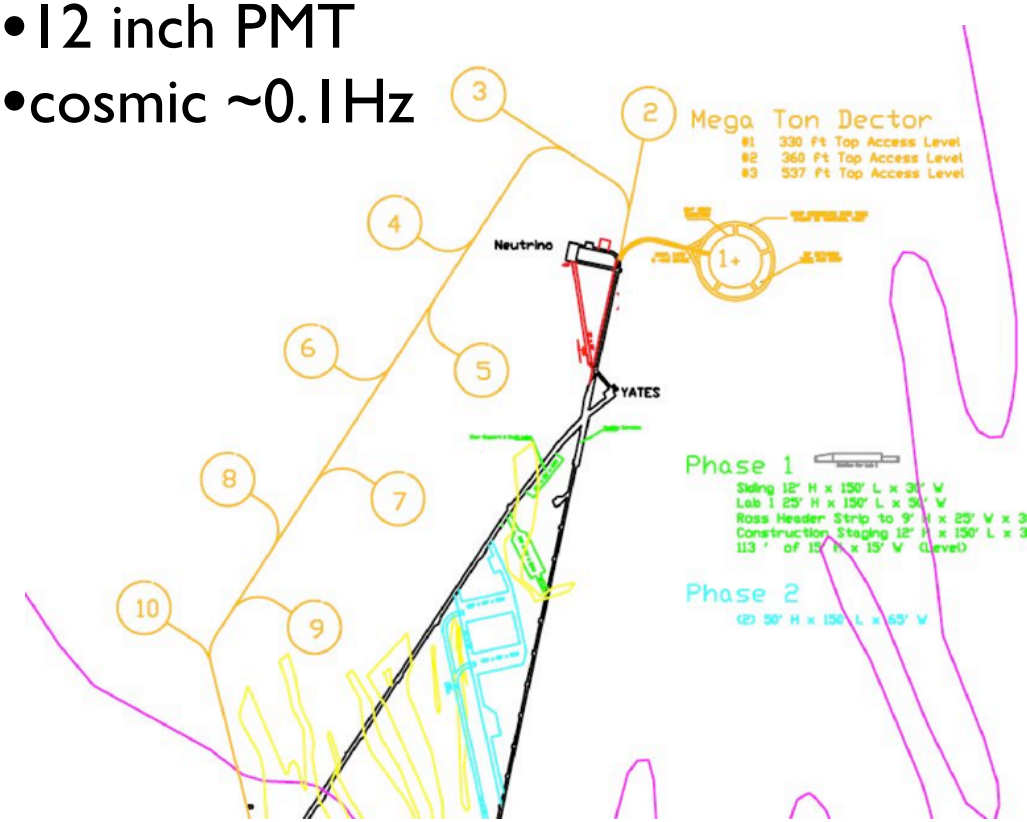
- To examine the concept of this project further Sally Dawson and Hugh Montegomery launched a joint study.
- The neutrino advisory group (NUSAG) of HEPAP was given a new charge to examine this project and compare it to other methods for CP studies in the neutrino sector.
- There were several meetings and many documents. All are at http://nwg.phy.bnl.gov/fnal-bnl
- Final report (May 9, 2007) FNAL-0801-AD-E, BNL-77973-2007-IR, arXiv:0705.4396
- This report is a major achievement of this LDRD. It has been used for preparation of the NUSAG report.
- Numerous talks by MDiwan, MDierxcksens, MBishai.

Detector at Homestake

Modular Detector

- ~50m dia/h
- 100kT fiducial
- 4850 mwe
- 25% PMT cov.
- 12 inch PMT
- cosmic ~0.1Hz





BNL-76798-2006-IR

- ✓Initial detector 3 modules
- ✓Space can be planned for 10
- ✓ Cost estimate $115M/module
- ✓6 yrs construction to first 100kT
- ✓8 yrs to full 300 kT.

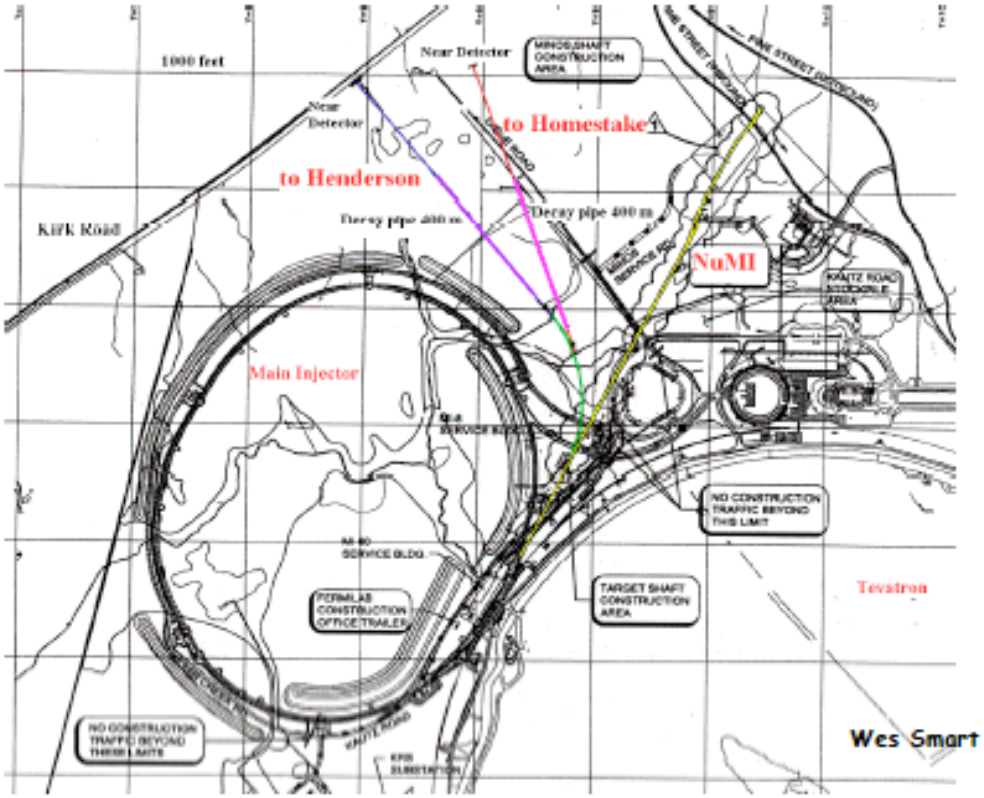
Fiducial vol depends on rock stability studies and PMT pressure rating.

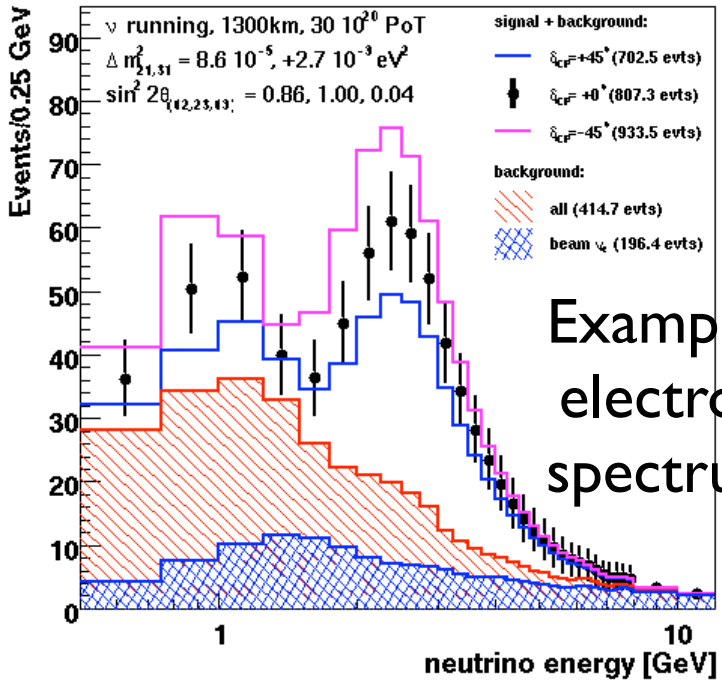
FNAL beam and detector simulations

Beam (angle)	Power	Detector	ν_μ CC	ν_μ CC osc	$\bar{\nu}_\mu$ CC	$\bar{\nu}_\mu$ CC osc
120 GeV (0 deg.)	0.7 MW	300 kT	207900	110300	78700	40000
120 GeV (0.5 deg.)	0.7 MW	300 kT	94500	40000	35200	13700
120 GeV (0.5 deg.)	1.3 MW	300 kT	176000	74100	65300	25400
120 GeV (0.5 deg.)	2.3 MW	300 kT	310500	131000	115600	45000
60 GeV (0 deg.)	1.6 MW	300 kT	362400	165600	120000	51100
40 GeV (0 deg.)	1.3 MW	300 kT	214500	85800	66300	25400

Recycler upgrade
Recycler upgrade
Accumulator
Proton driver (PD)
PD with MI@60GeV
PD with MI@40GeV

Total CC muon event rate at 1300 km in 5 yrs





Example simulated electron neutrino spectrum (all cuts)

$$Total\ POT(10^{20}) = \frac{Beam\ power(kW)}{1.6E_p(GeV)} \times time(10^7 sec)$$

Sensitivity comparison

Comparison of the sensitivity reach of different long baseline experiments given as the value of $\sin^2 2\theta_{13}$ at which 50% of δ_{cp} values will have $\geq 3\sigma$ reach for the choice of mass hierarchy with worst sensitivity. Total exposure assumes equal amounts of ν and $\bar{\nu}$:

Beam	Baseline	Detector	Exposure (MW.yr*)	$\theta_{13} \neq 0$	CPV	$sign(\Delta m^2_{31})$
NuMI ME, 0.9°	810 km	NOνA 20 kT	6.8	0.015	$>$ 0.2	0.15
NuMI ME, 0.8°	810 km	LAr 100 kT	6.8	0.002	0.03	0.05
NuMI LE, 0.8°, 3°,	810,700 km	LAr 2 $\times$ 50 kT	6.8	0.005	0.04	0.04
WBLE 120GeV, 0.5°	1300km	LAr 100 kT	6.8	0.0025	0.005	0.006
WBLE 120GeV, 0.5°	1300km	WCe 300 kT	6.8	0.006	0.03	0.011
WBLE 120GeV, 0.5°	1300km	WCe 300 kT	13.6	0.004	0.012	0.008

Some differences in calculations remain: 5% syst assumed for off-axis, 10% assumed for WBLE.

This table is a the snapshot of all the work from this LDRD